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Prospective evaluation of workflow interventions to improve biopsy turnaround time and slide quality

Mehata N[1], Sharma D[2]
[1, 2] **Associate Professor, department of Pathology, Index Medical College, Madhya Pradesh.**

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Corresponding Author: Dr Mehata N
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Abstract

Background: Turnaround time (TAT) and slide quality are key performance indicators in histopathology laboratories. Delays and suboptimal slides can adversely affect diagnosis, treatment planning, and institutional credibility. **Aim:** To prospectively evaluate biopsy-to-report TAT and slide quality in a tertiary histopathology laboratory, implement targeted workflow interventions, and assess their impact on overall efficiency and quality outcomes.

Methods: A prospective observational study was conducted in the Department of Pathology, Index Medical College, Malwanchal University, from October 2024 to June 2025. A total of 950 biopsy specimens were tracked from accession to report release. Workflow interventions included digital time-stamping, fixation time monitoring, batching control, and escalation for urgent cases. Slide adequacy, orientation, staining quality, and artefact rates were assessed pre- and post-intervention. Statistical analysis was performed using SPSS v22.0, with $p < 0.05$ considered significant.

Results: Median TAT decreased from 78.5 h to 54.3 h ($p < 0.001$). Adequately oriented slides improved from 85.6% to 94.8%, and artefact-free sections from 83.5% to 92.6%. Re-cut, re-stain, and addendum rates dropped significantly, reflecting enhanced laboratory precision and report completeness.

Conclusion: Structured process mapping and workflow interventions markedly improved efficiency and quality in histopathology reporting, establishing a sustainable model for laboratory quality assurance.

Key Words: Turnaround time; Histopathology; Slide quality; Workflow improvement; Quality assurance.

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Introduction

Timely surgical pathology reporting is a core quality indicator because delays can postpone treatment decisions, prolong hospital stay, and erode clinician confidence; hence, monitoring turnaround time (TAT) alongside slide adequacy/orientation and re-work rates is central to laboratory performance management [1]. Recent prospective and implementation studies from oncology and academic centers show that routine diagnostic biopsies still experience avoidable delay segments, with case complexity, special stains, and workflow fragmentation as key drivers [2]. Concurrently, digital enablers automation, scanner-based whole slide imaging (WSI), and standardized Lean/Six-Sigma practices have demonstrated measurable improvements in efficiency, pathologist workload balance, and reporting timeliness when deployed with process control and IT integration [3, 4]. Validation work also suggests that WSI can support rapid diagnostic tasks without compromising accuracy, creating opportunities to shorten non–value-added intervals in the reporting pathway [5].

This prospective study focuses on improving efficiency and quality in histopathology by evaluating the entire biopsy-to-report pathway. Delays in tissue processing, embedding, and sign-out often contribute to prolonged TAT, affecting patient care and clinical decision-making. Through workflow audits, time-stamping, and structured interventions such as controlled batching, fixation time monitoring, and escalation protocols for special stains, this research aims to identify bottlenecks and propose corrective measures. Integration of digital preview or whole slide imaging (WSI), where available, will facilitate early review of urgent cases and faster report finalization. The study will also benchmark key quality indicators—adequacy, orientation, and rework rates against international standards to establish sustainable quality improvements. With this a study is taken with an aim to prospectively evaluate biopsy-to-report TAT and slide quality in a tertiary histopathology laboratory, implement targeted workflow interventions, and assess their impact on TAT and quality metrics over 6–9 months.

Methods:

This prospective observational study was conducted in the department of Pathology, Index Medical College, Hospital and Research Centre, Malwanchal University, Indore, Madhya Pradesh, from October 2024 to June 2025**.** All biopsy samples received during the study period were included irrespective of the organ or diagnosis. Specimens with incomplete requisition forms, inadequate clinical data, or those requiring referral for expert opinion were excluded. Each case was tracked from the time of receipt in the

laboratory until final report dispatch. Time stamps were recorded for each step of the process sample receipt, grossing, processing, embedding, microtomy, staining, microscopic evaluation, and report sign-out to determine the duration of each sub-stage and total TAT. The study adhered to the ethical standards of the Institutional Ethics Committee, and confidentiality of patient information was maintained throughout.

Data were collected using a structured proforma specifically designed for this project. Grossing protocols followed departmental standard operating procedures (SOPs) to ensure uniformity. All tissues were fixed in 10% neutral buffered formalin, and fixation times were documented precisely. Processing and embedding were carried out using an automated tissue processor and paraffin embedding system. Microtomy was performed with rotary microtomes, and hematoxylin and eosin (H&E) staining was standardized using prevalidated reagents. Each slide was examined for adequacy, orientation, section thickness, staining quality, and presence of artefacts. Quality control (QC) parameters such as need for re-cutting, re-staining, and addendum issuance were also recorded. Inadequate or suboptimal slides were immediately flagged for corrective action, and the reasons for delays or rework were documented in detail.

Workflow improvement interventions were implemented midway through the study period after baseline data collection. These interventions included enforcing batching discipline, standardizing fixation time, ensuring proper labeling at accession, and introducing digital time-stamping for each stage to monitor real-time progress. Additionally, an escalation protocol was established for urgent cases and those requiring special stains or immunohistochemistry (IHC). Pathologists were encouraged to use digital preview systems or whole slide imaging (WSI) where available, to expedite preliminary assessment. After implementing the interventions, post-intervention data were collected for three months to compare performance metrics with baseline values.

Statistical analysis was carried out using SPSS software version 22.0**.** Continuous variables, such as mean and median TAT, were expressed as mean ± standard deviation and compared using Student's *t*-test or Mann–Whitney *U* test, depending on data distribution. Categorical data such as adequacy and re-cut rates were analyzed using the Chi-square test. A p-value < 0.05 was considered statistically significant. The outcomes were expressed as changes in median and 90th-percentile TAT, improvement in adequacy/orientation, and reduction in re-cut/re-stain rates. Findings were presented in tables and charts for visual comparison, and process flow diagrams were used to illustrate workflow efficiency before and after intervention.

Results:

A total of 950 biopsy specimen were analyzed during the study period, predominantly gastrointestinal (30.5%), followed by breast (18.9%) and skin biopsies (16.8%) (Table 1). The median baseline biopsy-to-report TAT was 78.5 hours, with a 90th-percentile TAT of 132 hours. Following workflow standardization and digital time-stamping, the median TAT reduced to 54.3 hours and the 90th-percentile to 98.7 hours, showing a statistically significant improvement ($p < 0.001$). Slide quality parameters demonstrated similar gains, with adequately oriented sections increasing from 85.6% to 94.8% and optimally stained slides from 88.3% to 96.2% ($p < 0.01$). Artefact-free sections also improved by 9.1% (Table 2). Quality-control metrics showed a reduction in re-cut (8.7% to 4.3%), re-stain (6.2% to 3.5%), and addendum (5.1% to 2.8%) rates, each statistically significant ($p < 0.05$) (Table 3). The improvement was attributed to better fixation monitoring, batching control, and enhanced coordination between technicians and pathologists. The introduction of digital preview and escalation protocols for urgent cases facilitated earlier microscopic review and rapid report finalization. Overall, the study demonstrated that structured process mapping and targeted interventions effectively reduced reporting delays and enhanced slide quality, establishing a sustainable framework for continuous quality improvement in the histopathology laboratory.

Discussion:

Table 1 shows the baseline distribution of biopsy specimens by type: gastrointestinal (30.5 %), breast (18.9 %), skin (16.8 %), lymph node (14.7 %), and others (18.9 %). This breakdown is valuable for interpreting the workload composition and planning resource allocation within the pathology laboratory. The dominance of gastrointestinal and breast biopsies aligns with published audits indicating that small-surgery and endoscopic biopsies often represent the largest share of specimens received in a surgical pathology service. For instance, one audit found that 42–50 % of material were "biopsy fragments" in general hospital labs [6, 7]. Having a higher proportion of skin and lymph node biopsies also underscores the need for versatility in fixation protocols and technician training across specimen types, since procedural variation (e.g., punch skin, excisional nodes) affects grossing, embedding, and processing times. Other studies emphasise that the nature of specimen type influences laboratory TAT and quality indicators, suggesting that labs should stratify performance metrics by specimen category [8]. Thus, the detailed breakdown in Table 1 supports benchmarking and tailoring of workflow improvements: for example, focusing fixation and batching interventions differently for endoscopic GI

versus skin biopsies, since their processing profiles may differ.

The reduction in median TAT from 78.5 hours to 54.3 hours, and the drop in the 90th-percentile TAT from 132 hours to 98.7 hours, reflect significant improvements in reporting efficiency. Previous studies show that routine biopsy diagnoses can often be completed within 2 working days (~48 hours) in well-resourced settings; for example, one inter-institutional review found that 85.9% of routine biopsies were signed out by the second working day [9]. In more complex cases, especially those requiring special stains or immunohistochemistry, median TATs around 2.7 days (≈65 hours) have been documented [10]. A recent prospective audit found an average TAT of about 3.7 ±2 days for diagnostic biopsies, with significant prolongation when ancillary techniques were required [1]. The observed improvements in our study thus align with the global benchmark trends and exceed many baseline figures from developing-world laboratories. The systematic review of lean methodology applied to laboratory workflows demonstrated up to 76% reduction in overall TAT when non-value-added steps were eliminated and digital or process innovations introduced [11]. Collectively, these data suggest that targeted workflow interventions such as time-stamping, fixation monitoring, batching discipline, and digital preview of urgent cases are effective levers to compress reporting intervals and reduce variation in TAT.

In the first phase of the study, baseline slide quality metrics showed 85.6% of sections had adequate orientation, 88.3% optimal staining, and 83.5% artefact-free sections, which improved after intervention to 94.8%, 96.2%, and 92.6% respectively (Table 2). These gains illustrate that targeted workflow interventions such as fixation monitoring, improved embedding/microtomy discipline, and technician/pathologist coordination can significantly elevate the technical quality of histologic preparations. The literature supports that slide-section adequacy (orientation, thickness, absence of extraneous tissue) and staining consistency are central quality indicators in surgical pathology laboratories, and that deficiencies in these areas contribute to diagnostic delays, increased re-cuts/re-stains and higher error rates [12, 13]. For instance, reviews highlight that over 70-80% of laboratory errors arise in the pre-analytical and analytic phases (which include sectioning/staining) of histology processing [12]. In our context, the improvement in adequately oriented sections by 9.2 percentage points suggests that our fixation-to-cut workflow, embedding discipline and technician training were effective. The 7.9 % rise in optimally stained sections and 9.1 % drop in artefact incidence further indicate that slide-making technicalities were improved—important because poor staining or artefacts hamper pathologist review and may trigger re-work or addenda. Comparable studies have shown that when slide quality standards are audited and feedback delivered, rework rates drop and pathologist satisfaction increases [13].

It is worthwhile to reflect on the clinical and operational implications of these improvements. Higher rates of adequately oriented and artefact-free slides enable pathologists to render diagnoses more confidently and may reduce the need for micro-cuts, re-staining or requesting additional levels—thus shortening sign-out time and contributing indirectly to improved turnaround time. Several studies have documented that improved histologic section quality correlates with faster sign-out and fewer diagnostic amendments [14]. In our workflow, the reduction in re-cut (8.7%→4.3%) and re-stain (6.2%→3.5%) rates mirrors the improved slide-quality metrics, underscoring the value of focusing on slide preparation quality as a key driver of overall laboratory performance. Importantly, the sustained improvement in slide quality also supports implementation of standard-operating-procedures (SOPs) and ongoing technician competency review, which literature identifies as essential for durability of quality gains [15]. Overall, the results validate that structured attention to slide orientation, staining quality and artefact reduction is not only technically beneficial but also operationally impactful improving diagnostic workflow, reducing rework, and enhancing the laboratory's quality profile.

In our study, the reduction in re-cut slides from 8.7% to 4.3%, re-stain slides from 6.2% to 3.5%, and addendum reports from 5.1% to 2.8% indicate measurable improvement in histology workflow quality and diagnostic stability (Table 3). These metrics are inter-related: fewer re-cuts or re-stains suggest that the initial slide preparation, sectioning, staining and embedding were more consistent and required less correction; likewise, fewer addenda reflect more complete and accurate initial reports, minimizing the need for supplemental updates. Literature supports that frequent "repeat slide" events (re-cuts/re-stains) are meaningful indicators of internal analytic phase inefficiency one study reported that when repeat slide rates exceeded 3-5% the facility often had unaddressed process gaps [16]. Moreover, systematic audits of amended or addendum reports show that though interpretative error rates may be low (<0.5-1%), the existence of addenda often signals lingering pre-analytic or analytic imperfections that cascade into downstream diagnostic delay or clinician re-engagement [1, 12].

From an operational standpoint, the drop in addendum rate from 5.1% to 2.8% is particularly encouraging because addenda not only reflect slide- or report-related corrections, but also carry implications for patient care, clinician communication and medico-legal risk. A recent

eight-year institutional study found amendment/addendum rates around 0.15% in over 100 000 reports, though this was a high-volume U.S. centre with mature QA systems [17]. In contrast, laboratories in resource-limited settings frequently report higher repeat slide and addendum frequencies, which align with the baseline metrics of our setting and underscore the value of targeted intervention. By introducing time-stamping, batching discipline, fixation documentation, and digital preview for urgent cases, our study demonstrates that focused process control can significantly reduce re-work and addendum burden. Fewer re-cuts/re-stains translate into lower consumable costs, technician time savings, and faster slide throughput; fewer addenda mean more robust first-pass diagnoses and stronger clinician confidence. These quality gains also support continuous improvement cycles by reducing variation, enabling meaningful benchmarking, and facilitating lean management of histopathology workflows [12, 13].

Conclusion: This prospective quality improvement study demonstrated that structured workflow interventions significantly enhanced both turnaround time and technical quality in surgical pathology. By implementing time-stamping, fixation monitoring, batching discipline, and digital preview systems, the laboratory achieved substantial reductions in median TAT, re-cut, re-stain, and addendum rates, along with notable improvements in slide adequacy, orientation, and staining consistency. These findings highlight that continuous process auditing and adherence to standardized operating procedures can lead to sustainable efficiency gains, improved diagnostic accuracy, and higher clinician satisfaction, establishing a reproducible model for quality enhancement in histopathology laboratories.

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Table 1: Baseline Distribution of Biopsy Specimens

Specimen	Number	%	Fixation time	Processing time
Gastrointestinal	290	30.5	12.8 ± 3.4	9.5 ± 2.6
Breast	180	18.9	14.2 ± 4.1	10.1 ± 2.9
Skin	160	16.8	10.4 ± 3.2	8.7 ± 2.5
Lymph node	140	14.7	13.1 ± 3.8	9.2 ± 3.0
Others	180	18.9	11.6 ± 3.7	9.0 ± 2.2

Fixation time and processing time Mean ± SD in hours

Table 2: Slide quality parameters before and after intervention in %

Parameter	Intervention		Improvement	p-value
	Pre	Post		
Adequately oriented sections	85.6	94.8	9.2	0.004
Optimal staining	88.3	96.2	7.9	0.002
Artefact-free sections	83.5	92.6	9.1	0.003

Table 3: Re-cut, re-stain and addendum rates in %

Parameter	Intervention		Reduction	p-value
	Pre	Post		
Re-cut slides	8.7	4.3	-4.4	0.01
Re-stain slides	6.2	3.5	-2.7	0.03
Addendum reports	5.1	2.8	-2.3	0.04